Claims

We claim the following inventions:

1. A method of inspecting and/or characterizing a substrate, comprising:

    obtaining a first dataset, wherein said first dataset includes data derived from an image collected by a first detector of a first region of said substrate;

    obtaining a second dataset, wherein said second dataset includes data derived from an image collected by a second detector of at least a portion of said first region of said substrate;

    obtaining a third dataset, wherein said third dataset includes data derived from an image collected by said first detector from a second region of said substrate, wherein said second region of said substrate is expected to be substantially identical to said first region;

    obtaining a fourth dataset, wherein said fourth dataset includes data derived from an image collected by said second detector of at least a portion of said second region of said substrate; and

    processing information derived from said first, second, third, and fourth datasets to determine whether a defect exists in at least one of said first or second regions.

2. The method of Claim 1 wherein the step of processing information comprises:

    calculating the difference signal for each pixel with said first detector,

    calculating the difference signal for each pixel with said second detector,

    performing a mathematical operation on the two difference signals, and

    comparing the result of said operation with a threshold.

3. A method of inspecting and/or characterizing a substrate, wherein said substrate includes a plurality of substantially identical features, the method comprising:

    obtaining a first dataset wherein said first dataset includes data derived from an image collected by a first detector of a first region of said substrate, and wherein said region includes an array of substantially identical repeating features;

    obtaining a second dataset, wherein said second dataset includes data derived from an image collected by a second detector of at least a portion of said first region of said substrate; and

    processing information derived from at least said first dataset to determine whether differences exist between a first portion of said repeating features and a second portion of said repeating features.

4. A method of inspecting and/or characterizing a substrate, wherein said substrate includes a plurality of substantially identical features, the method comprising:

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obtaining a first dataset wherein said first dataset includes data derived from an image collected by a first detector of a first region of said substrate, and wherein said region includes an array of substantially identical repeating features;

obtaining a second dataset, wherein said second dataset includes data derived from an image collected by a second detector of at least a portion of said first region of said substrate; and

processing information derived from at least said first dataset to identify a nonrepeating portion within said array.

5. The method of Claim 4, wherein said processing includes a step of transforming the image, filtering the Fourier transform in the frequency domain to remove the repeating pattern in the spatial domain, and performing an inverse transform of said transformed image.

6. The method of Claim 5, wherein the nonrepeating portion represents a defect.

7. A method of inspecting and/or characterizing a substrate, wherein said substrate includes a plurality of substantially identical features, the method comprising:

obtaining a first dataset wherein said first dataset includes data derived from an image collected by a first detector of a first region of said substrate, and wherein said region includes an array of substantially identical repeating features;

obtaining a second dataset, wherein said second dataset includes data derived from an image collected by a second detector of at least a portion of said first region of said substrate;

obtaining a third dataset, wherein said third dataset includes data derived from an image collected by said first detector from a second region of said substrate, wherein said second region of said substrate is expected to be substantially identical to said first region;

obtaining a fourth dataset, wherein said fourth dataset includes data derived from an image collected by said second detector of at least portion of said second region of said substrate; and

obtaining a fifth dataset, wherein said fifth dataset includes data derived from an image collected by said first detector from a third region of said substrate, wherein said third region of said substrate is expected to be substantially identical to said first and second regions; and

using said fifth dataset to assist in arbitrating which of said first and second regions contains a defect.

8. A method of redetecting a defect which was detected during a previous inspection of a substrate, wherein said substrate includes a plurality of substantially identical features, the method comprising:

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obtaining a first dataset, wherein said first dataset includes data derived from an image collected by a first detector of a first region of said substrate, and wherein said first region is known to contain a defect found during a previous inspection;

obtaining a second dataset, wherein said second dataset includes data derived from an image collected by a second detector of at least a portion of said first region of said substrate;

obtaining a third dataset, wherein said third dataset includes data derived from an image collected by said first detector from a second region of said substrate, wherein said second region of said substrate is expected to be substantially identical to said first region;

obtaining a fourth dataset, wherein said fourth dataset includes data derived from an image collected by said second detector of at least a portion of said second region of said substrate; and

processing information derived from said first, second, third, and fourth datasets to redetect said previously found defect in said first region.

9. A method of inspecting and/or characterizing a substrate, wherein said substrate includes a plurality of substantially identical features, the method comprising:

obtaining a first dataset wherein said first dataset includes data derived from an image collected by a first detector of a first region of said substrate, and wherein said region includes an array of substantially identical repeating features;

obtaining a second dataset, wherein said second dataset includes data derived from an image collected by a second detector of at least a portion of said first region of said substrate; and

combining analog information within said first and second datasets.

10. The method of Claim 9, further comprising digitizing at least a portion of said first dataset, said second dataset and/or said combined analog information.

11. A method of inspecting an object, comprising:

exposing at least a portion of said object to a beam of charged particles; and

detecting particles from portion of said object using at least two detectors, wherein at least one of said detectors detects a multipixel image.

12. The method of Claim 11, wherein said charged particles are electrons.

13. The method of Claim 11, wherein said object is selected from the group consisting of semiconductor wafers, singulated die, package substrates, reticles and photomasks.

14. The method of Claim 11, wherein said multipixel image is acquired using a time delay integration sensor.

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15. The method of Claim 11, wherein output from each of said detectors is compared to determine whether a defect is present on said object.

16. The method of Claim 11, wherein a plurality of portions of said object are inspected, and datasets derived from said detectors are compared to detect differences in at least some of said plurality of portions.

17. The method of Claim 1, wherein said information is processed by combining a first function representing a comparison of said first and third datasets with a second function representing a comparison of said second and fourth datasets.

18. The method of Claim 17, wherein said comparison is an image subtraction.

19. The method of Claim 17, wherein said combination represents a third function including summing said first function squared with said second function squared.

20. The method of Claim 17, wherein said combination is compared against a predetermined range of values to determine whether a defect exists.

21. A method of inspecting and/or characterizing a substrate, wherein said substrate is selected from the group consisting of semiconductor wafers, singulated die, package substrates, reticles and photomasks, the method comprising:

   exposing said substrate to at least a first source of charged particles:

   detecting charged particles emitted from said substrate with at least two detectors, wherein said substrate is moved continuously relative to said source of charged particles during said exposure step.

22. The method of Claim 21, wherein said charged particles are electrons.

23. The method of Claim 22, wherein said electrons are provided as a focused beam.

24. The method of Claim 21, wherein said substrate is moved by a stage during said exposure.

25. The method of Claim 24, wherein said stage is moved at a substantially constant velocity.

26. The method of Claim 21, wherein said two detectors detect charged particles from different ranges of azimuthal angles relative to said substrate.

27. The method of Claim 21, wherein said two detectors detect charged particles emitted from different ranges of elevation angles relative to said substrate.

28. The method of Claim 20, wherein at least two portions of said substrate are exposed to said particles, and wherein said detectors are used to detect charged particles

emitted from said portions, and wherein data from said detectors is used to determine whether potential defects exist within said portions.

29. A method of inspecting and/or characterizing a substrate, comprising:

obtaining a first dataset, wherein said first dataset includes data derived from an image collected by a first electron detector of a first region of said substrate;

obtaining a second dataset, wherein said second dataset includes data derived from an image collected by a second electron detector of at least a portion of said first region of said substrate;

obtaining a third dataset, wherein said third dataset includes data derived from an image collected by said first electron detector from a second region of said substrate, wherein said second region of said substrate is expected to be substantially identical to said first region;

obtaining a fourth dataset, wherein said fourth dataset includes data derived from an image collected by said second electron detector of at least a portion of said second region of said substrate;

processing information derived from said first, second, third, and fourth datasets to determine whether a defect exists in at least one of said first or second regions;

obtain a fifth dataset, wherein said fifth dataset includes data derived from an image collected by an X-ray detector of at least a portion of said first region and/or said second region of said substrate; and

processing materials from said fifth dataset to identify the materials in the defective and non-defective areas of said first region and/or said second region.

30. A method of inspecting and/or characterizing a substrate, wherein said substrate includes a plurality of substantially identical features, comprising:

obtaining a first dataset, wherein said first dataset includes data derived from an image collected by an electron detector of a first region of said substrate;

obtaining a second dataset, wherein said second dataset includes data derived from an image collected by an X-ray detector of at least a portion of said first region of said substrate;

obtaining a third dataset, wherein said third dataset includes data derived from an image collected by said electron detector from a second region of said substrate, wherein said second region of said substrate is expected to be substantially identical to said first region;

obtaining a fourth dataset, wherein said fourth dataset includes data derived from an image collected by said X-ray detector of at least a portion of said second region of said substrate; and

processing information derived from said first, second, third, and fourth datasets to determine whether a defect exists in at least one of said first or second regions.

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31. A method of inspecting and/or characterizing a substrate, wherein said substrate includes a plurality of substantially identical features, the method comprising:

obtaining a first dataset wherein said first dataset includes data derived from an image collected by an X-ray detector of a first region of said substrate;

obtaining a second dataset, wherein said second dataset includes data derived from an image collected by said X-ray detector from a second region of said substrate, wherein said second region of said substrate is expected to be substantially identical to said first region;

obtaining a third dataset, wherein said third dataset includes data derived from an image collected by said X-ray detector from a third region of said substrate, wherein said third region of said substrate is expected to be substantially identical to said first and second regions; and

using said third dataset to assist in arbitrating which of said first and second regions contains a defect.

32. A method of inspecting and/or characterizing a substrate, wherein said substrate includes a plurality of substantially identical features, the method comprising:

obtaining a first dataset wherein said first dataset includes data derived from an image collected by a first detector of a first region of said substrate;

obtaining a second dataset, wherein said second dataset includes data derived from an image collected by a second detector from a second region of said substrate, wherein said second region of said substrate is expected to be substantially identical to said first region;

generating an image of said first region based on the substrate designer's database; and

comparing the image data from said first detector and said second detector with the image based on the substrate designer's database to identify defects in said first region.

33. A method of classifying defects on a substrate, wherein said substrate includes a plurality of substantially identical features, the method comprising:

obtaining a first dataset, wherein said first dataset includes data derived from an image collected by a first detector of a first region of said substrate;

obtaining a second dataset, wherein said second dataset includes data derived from an image collected by a second detector of at least a portion of said first region of said substrate;

obtaining a third dataset, wherein said third dataset includes data derived from an image collected by said first detector from a second region of said substrate, wherein said second region of said substrate is expected to be substantially identical to said first region;

obtaining a fourth dataset, wherein said fourth dataset includes data derived from an image collected by said second detector of at least a portion of said second region of said substrate; and

processing information derived from said first, second, third, and fourth datasets to calculate a composite difference signal, and

identifying and classifying the defects on the basis of the composite difference signal.

34. A method of inspecting a substrate wherein said substrate includes a plurality of substantially identical features, the method comprising:

exposing a portion of said substrate to a particle beam

obtaining a dataset which includes data derived from an image collected by a detector of a region of said substrate, said region containing a plurality of substantially identical features; and

processing the dataset to determine whether differences exist between a first portion of said repeating features and a second portion of said repeating features.

35. The method of Claim 34 wherein said processing comprises:

expressing the image data for one cell on the die as a matrix of pixels with numerical gray scale values;

expressing the image data for a nominally identical second cell on the same die as a matrix of pixels with numerical gray scale values;

aligning the two matrices to ensure that the analogous places in the two matrices contain the gray scale values for corresponding pixels in the nominally identical cells; and

creating a difference map by subtracting the gray-scale values for corresponding pixels.

36. The method of Claim 34 wherein said processing consists of the following steps:

transforming the image data from the spatial domain into the frequency domain,

filtering the Fourier transform in the frequency domain to remove at least a portion of the repeating pattern in the spatial domain, and

performing an inverse transform of the transformed image.

37. A method of inspecting and/or characterizing a substrate with an electron-beam inspection system that contains two or more detectors, comprising filtering backscattered electrons to substantially prevent said backscattered electrons form reaching at least one of said detectors.

38. A method of inspecting and/or characterizing a substrate with an electron-beam inspection system that contains two or more detectors, comprising using a dispersive

element to cause low-energy electrons to strike one detector and high-energy electrons to strike another detector.

39. The method of Claim 38 wherein said dispersive element comprises a magnetic separator.

40. The method of Claim 38 wherein said dispersive element comprises an energy-dispersive prism.

41. The method of Claim 38 wherein said dispersive element comprises a Wien filter.

43. A method of inspecting or reviewing a substrate, comprising:

   a. exposing at least a portion of said substrate, thereby causing said substrate to emit charged particles;

   b. detecting said charged particles with a first detector element;

   c. detecting said charged particles with a second detector element; and

   d. combining signals from said first detector element and said second detector element, such that topographical data concerning said substrate is enhanced.

44. The method of claim 43, wherein said signals are subtracted from one another.

45. The method of claim 44, wherein material contrast is suppressed.

46. The method of claim 43, wherein said signals are in analog form when combined.

47. The method of claim 43, wherein said signals are digitized before being combined.

48. The method of claim 43, wherein said signals are summed.

49. The method of claim 43, wherein said signal combination is controlled to create a predetermined mix of topographic and material contrast.